Richardson, Kimball, Angot, Abbot, and others have conducted investigations regarding the relation between the intensity of solar radiation at the outer limits of the earth's atmosphere and the intensity at the earth's surface. Although the problem is complex, some conclusions of great value have been drawn. It is probable that these conclusions, together with the limits which can be set on the values of ($\bar{R}$), will be of great value in connection with theories of climatic change, particularly glaciation.

The kind interest which Doctor McEwen of this institution has taken in the preparation of this paper, and also the valuable suggestions he has offered, are gratefully acknowledged.

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CHICAGO'S GREATEST SNOWSTORM, MARCH 25–26, 1930

By Owen T. Lay

[Westher Bureau office, Chicago, Ill., April 14, 1930]

The greatest snowstorm in the history of Chicago occured on March 25–26, 1930. The total amount of snow was 19.2 inches (average depth) at the Weather Bureau observatory at the University of Chicago. The snow was badly drifted by the wind, and drifts 4 to 5 feet deep were to be found in all portions of the city. The storm continued without interruption for 43 hours and 45 minutes. The depth of 19.2 inches exceeded by 4.3 inches the total snowfall from any other single storm at Chicago, the previous record being 14.9 inches on January 6–7, 1918.

GENERAL METEOROLOGICAL CONDITIONS

On the evening of March 22, 1930, a barometric depression covered most of the Rocky Mountain region and Great Plains. By 7 a. m. on tha 23d it had deepened somewhat and moved eastward, there then being two centers of lowest pressure, 29.60 inches in eastern North Dakota and 29.62 inches in central Iowa. Snow was falling over Wisconsin and eastern Minnesota. Within the next 12 hours there was little change in the intensity of the storm and both centers moved slowly east-southeastward, with rain in Illinois and southern Wisconsin and mostly cloudy weather thence northwestward.

By the morning of the 24th the northern center had practically disappeared and the southern center had moved from southeastern Iowa to west-central Indiana, with little change in intensity. During the next 12 hours, ending at 7 p. m. on the 24th, the center had advanced to extreme eastern Ohio but appeared only as a loop in the isobar, while a new center had apparently developed over southeastern Missouri and advanced to southern Indiana.

During the next 12 hours, ending at 7 a. m. on the 25th, the center over southern Indiana remained practically stationary with an increase in intensity from 29.54 inches to 29.28 inches, while the eastern loop had disappeared. By evening the main center of the storm had advanced to western Lake Ontario, but another center was left over east-central Indiana. By the morning of the 26th the eastern center had advanced to extreme southern Quebec, Montreal, 29.04 inches, and the western center had moved north-northeastward to the Georgian Bay region, Parry Sound, 28.98 inches, and by the night of the 26th the eastern center had practically disappeared and the western center continued to move north-northeastward, Doucet, Quebec, 29.10 inches.

The heaviest snow at Chicago occurred on the 25th with strong northeast winds from off Lake Michigan. These winds persisted throughout the 25th up to about 6 p. m., ninetieth meridian time, when they backed to northwest and continued from that direction until 8:55 p. m. of the 26th. Gust velocities on the 25th ranged from 35 to 50 miles an hour from the northeast. During this time the storm center was over central and southern Indiana where it remained practically stationary for about 24 hours. That fact remains to be explained; apparently it was due to the advance from the west of a fresh fall in the barometer that sent the surface pressure down to 29.28 inches, and naturally caused strong northeast winds to continue to blow over the southern end of Lake Michigan with the results described herein.

LOCAL CHARACTERISTICS OF THE STORM

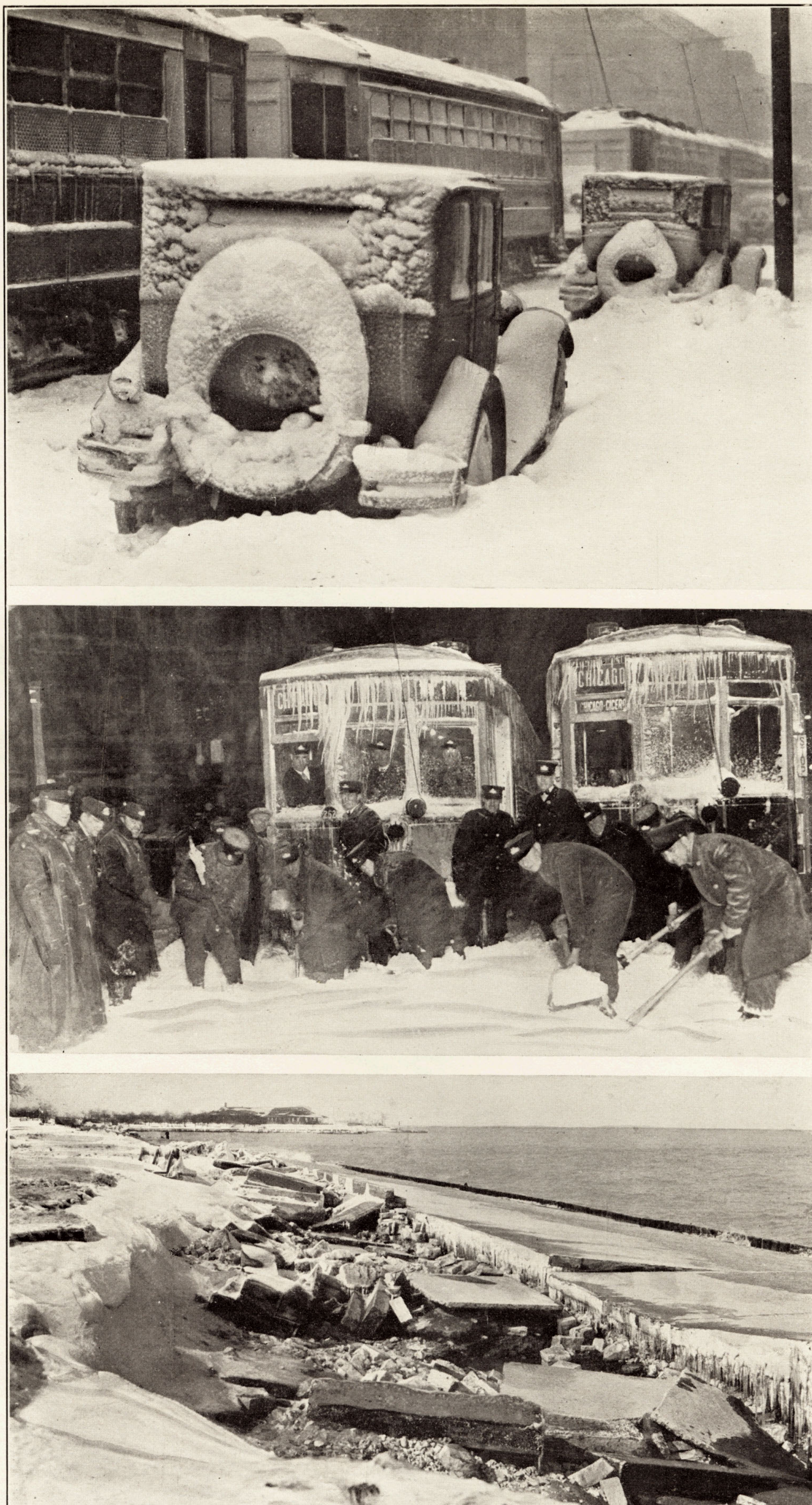
Starting with rain on the 24th, the temperature fell slowly and the rain first became mixed with sleet, then changed to snow. The air became filled with large snowflakes, and the wet character of the snow at first, in connection with high northeast winds, caused it to adhere to automobile windshields, windows, and buildings. Many accidents resulted during this period of poor visibility, which extended through most of the 25th.

The lateness of the season added an element of surprise and unpreparedness. Few automobiles were equipped with chains, and transportation organizations were not in readiness to combat the storm.

EFFECTS

The continued stalling of automobiles and trucks on car tracks made the constant operation of snow plows and street cars difficult or even impossible. Furthermore, automobile and truck traffic early in the storm served to pack the wet snow into soft ice that later had to be removed from street-car tracks by the use of picks and shovels. Many automobiles were abandoned in the streets. By noon on the 25th surface car service was practically at a standstill, suburban trains were moving with difficulty, and deliveries by motor vehicle had almost ceased. This imposed an extra burden upon the elevated lines, and that service was slowed up greatly because of the great crowds at the stations and on the trains.

Workers experienced much difficulty in reaching their places of employment and in returning to their homes on the 25th and 26th, and the down-town hotels were crowded. Many places of business closed early to enable their employees to reach their homes. In many cases those who came to work or returned home floundered through the snow for several miles to reach transportation that was moving on elevated tracks.



(Upper) clinging tendency of wet snow early in storm; (middle) clearing the way for street cars that could go no farther into drifted snow; (lower) damage shown along the lake front after most of the snow had melted. Wind damage lost sight of in most of the accounts of the storm because of the more spectacular struggle against the snow. (All three photographs the courtesy of Chicago Evening American, March 28, 1930).

(To face p. 147)

FIGURE 2.—Weather chart March 23, 1930

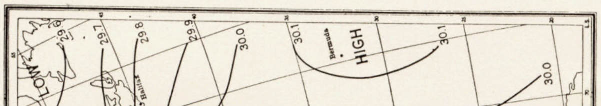


FIGURE 3.—Weather chart of March 24, 1930

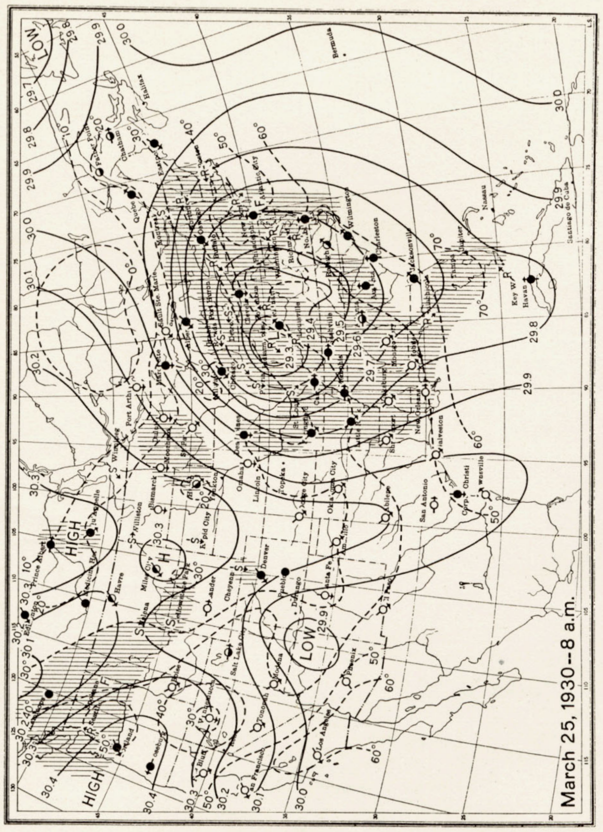


FIGURE 4.—Weather chart of March 25, 1930

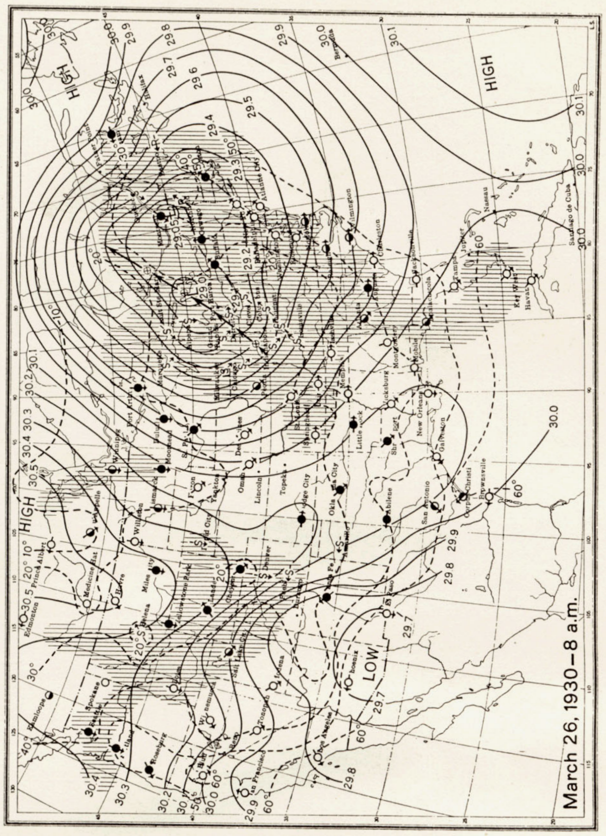


FIGURE 5.—Weather chart of March 26, 1930

School attendance was small on the 25th, and the city schools were closed on the 26th and 27th. On the first day of the storm milk deliveries to the city were cut down about 40 per cent, and appeals were broadcast by radio for farmers and others who ordinarily deliver milk to make every effort to reach the city and thereby prevent a milk famine. Milk valued at about $40,000 was lost on the highways the first day of the storm.

Airplane traffic ceased for three or four days, because of poor visibility the first two days and the fact that great drifts of snow were left on the landing fields, and the runways had to be cleared before planes could take off or land. At Waterman, Ill., about 50 miles west of Chicago, the total depth of snow was only 3 inches, and one of the transcontinental lines used the emergency landing field there as a base for mail that was handled between Chicago and that place by train.

Stocks of some goods became low or even exhausted in many outlying stores that depended upon trucks for frequent deliveries. This was particularly true as regards bread and perishable vegetables.

Citizens in all sections of the city and in the surrounding territory spent many hours in clearing walks, alleys, and driveways, but little permanent relief was possible until after the snow and high wind had ceased on the night of the 26th.

The Chicago Surface Lines, possibly the greatest sufferer, employed as many as 20,000 men with picks, shovels, and all available mechanical equipment in digging the tracks out. The storm cost that organization approximately $1,000,000. Other organizations and individuals were required to expend much money and effort on account of the storm. Stocks of tools for handling snow and ice became exhausted in many stores, and automobile repair shops were kept busy in replacing broken springs, burned out clutches, and other repair work. It seems safe to state that the storm cost the community several million dollars.

Considerable damage was caused along the lake front by the pounding of waves during the early portion of the storm when strong northeast winds prevailed, but this effect was lost sight of in reports at the time because of the more spectacular snowstorm.

The snow disappeared quickly, and without flooding. This was possible because the ground under the snow was fairly dry and not frozen, the great amount of evaporation owing to low relative humidity following the storm, and the fact that the temperature was slow in rising above the freezing point.

DISCUSSION

For some years I have been greatly interested in pronounced abnormalities in the weather. The heavy snow described by Mr. Lay in the preceding article must be considered as one of the greatest abnormal snows east of the Mississippi in the last half century. The March, 1888, blizzard, as it is frequently called, is another striking example of very heavy snow in late winter. The two storms had some points in common and differed materially in others. The area of heavy snow and its maximum depth in the Chicago storm was much less than in the March, 1888, storm. A depth of 40 inches and more in the last named was registered over a considerable area in Connecticut and the area affected by the storm was tenfold to twentyfold greater than was the case in the Chicago storm. Points of similarity are as follows: The great depth of snow in both storms was due to the retardation of the storm's progressive motion eastward due to strong areas of high pressure to the northeastward. Both storms developed great intensity from the trough form of barometric depression.

It is convenient to consider the Chicago storm from the view-point of surface-pressure distribution as influenced by the free-air temperature directly above the storm center. (Fig. 2.)

Weather chart March 23, 1930.—The most significant feature of this chart is the crescent-shaped depression of the barometer that extends from Canada to Mexico east of the Rocky Mountains with three centers of low pressure as shown. This depression is flanked on both the east and the west by anticyclones of considerable magnitude but great contrasts of temperature on the surface at least, are missing.

From the forecast division's upper-air chart I glean the following: The winds above the barometric depression were from a southerly direction in the free air up to the 1,500-meter level (4,900 feet). Above that level, at 2,000 meters (6,600 feet), some of the southerly winds at the 1,500-meter level have become west winds but the northerly component continues at about half the stations. The velocities of these winds from the south at 2,000 meters ranged from 10 meters per second, hereinafter abbreviated to m. p. s., over North Dakota, to 16 m. p. s. over southeastern Kansas, which regions conform in a general way with the centers of lowest pressure; from this fact two assumptions are justifiable, first, a mass of warmer air overlies and is partly the cause of the low surface pressure and, second, since the winds from the south begin to thin out above 1,500 meters, the seat of energy of the cyclone must be at or near that level.

The upper-air chart for 8 p. m. of the 23d shows that the area of southerly winds has progressed toward the east, though not at precisely the same speed as the surface barometric depression. The surface wind-shift line has made but little progress eastward because of the presence of a secondary circulation centered over north-central Minnesota. Evidence of this secondary is found in the loop far to the northwest of the isobar of 29.90 inches on the chart for March 24.

Weather chart March 24, 1930 (fig. 3).—This chart shows a change in the orientation of the depression of the morning of March 23, the longer axis of which now trends northeast-southwest with its center over central Indiana. There is also considerable surface warming in the Ohio Valley and doubtless in the free air above the center of lowest pressure where winds from a southerly direction continue but have spread somewhat to the eastward of the low-pressure center.

Weather chart March 25, 1920 (fig. 4).—The significant feature on this chart is a fall in pressure at the center of the cyclone and consequently an increase in the barometric gradients especially those in the northwest sector of the cyclone. At this time the cyclonic circulation also seems to have bored upward to a greater height than previously indicated by the free-air winds. The surface wind at Sault Ste. Marie, Mich., was from the northeast as required by the cyclonic circulation; at 3,300 meters (10,827 feet) it was from the east with a speed of 16 m.p.s., still cyclonic. Elsewhere the surface winds and those up to 2,000 meters were still from a southerly direction although at some points a shift to westerly had taken place. From this it may be inferred that the center of the cyclone in the free air was somewhat displaced toward the northwest.

Weather chart March 26, 1930 (fig. 5).—Here we have an example of a vast cyclonic whirl that has become of exceptional extent and intensity almost in the center of the continent. Although the cyclone is figured as having two centers, one of 29.00 inches, the other of 29.05 inches one can not but wonder whether the real center is at either point. The cyclone extends in an east-west direction about 1,700 miles and in a north-south direction about 2,200 miles.

By the morning of the 26th the upper-air winds at 1,500 meters have changed from southerly to westerly as far east as the Atlantic coast. The velocities ranged from 10 to 20 m.p.s. At 3,000 meters still higher speeds were found, the maximum being 36 m.p.s. at Jacksonville, Fla., on the outskirts of the cyclone. The two centers shown on the chart for the 26th had disappeared by the morning of the 27th and pressure at the cyclone center had risen somewhat. Its course thence to the northeast was uneventful.—*A. J. Henry.*

GULF STREAM DAILY THERMOGRAMS ACROSS THE STRAITS OF FLORIDA[1]

By CHARLES F. BROOKS

[Clark University, Worcester, Mass., April 5, 1930]

SYNOPSIS

During the past four years the Gulf Stream has been subjected to investigation by sea-water thermographs on crossing ships. Details of temperature, including alternating masses of warmer and cooler water, diurnal ranges of temperature, and rapid changes in distribution, have been written on the thermograms to form an amazingly complex picture.

bound trip gives a night profile and the northbound a daytime one. From night to day in sunny quiet weather the sea temperature at the surface rises 3° or 4° F. and at a depth of 6 feet about 2°. In windy weather the diurnal range is reduced by stirring to 1° or less.

The summer profile is characteristically warmer in the north than in the south, while the temperature of Key West Harbor stands out several degrees above the Gulf Stream. A band of cool water is almost always traversed within a mile of the Cuban shore, apparently where swell and current striking the steeply sloping bottom bring cool water to the surface. Similar cool water often occurs likewise at the margin of shoal water south of Key West. The winter profile is usually 2° or more warmer in the south than in the north portion of the straits. A narrow zone of probably upwelling water several degrees cooler than on either side usually divides the warmer water from the cooler. This boundary shifts many miles with wind and other effects that bring at one time more water direct from the Caribbean and at another time from the Gulf. Great variations sometimes occur in the course of a few hours.

Storms, chiefly through their stirring action, reduce the surface temperatures by 1° or more. Strong cold winds have an even greater effect than hurricanes, for they chill the water considerably as well as mix the warm surface layer with the cooler substrata.

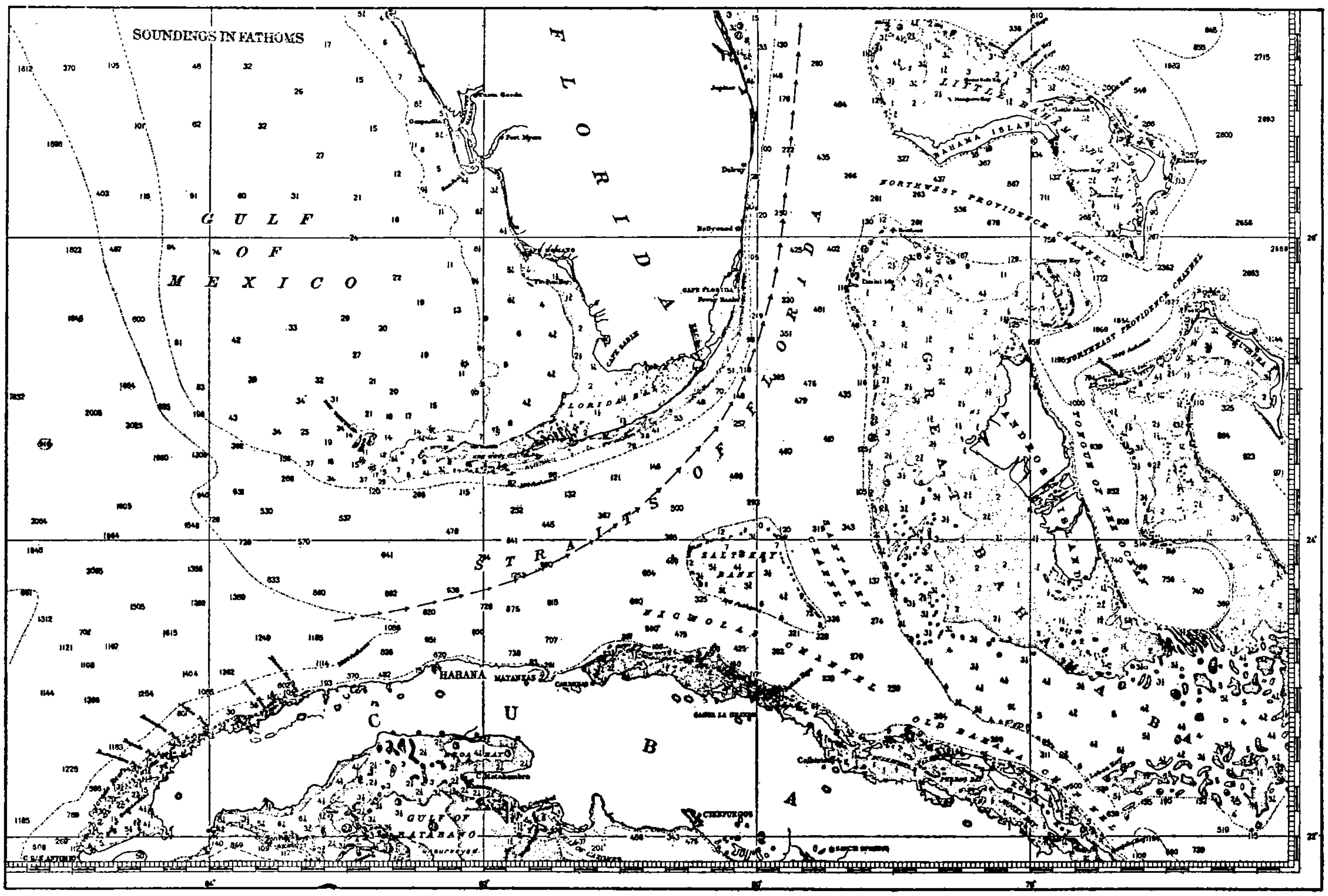


FIGURE 1.—Hydrographic features of the Gulf Stream within the Straits of Florida. (Adapted from United States Coast and Geodetic Survey Chart 1007 by the American Geographical Society for the *Geographical Review*, July, 1929.)

The thermograph is a mercury-in-steel bulb and capillary type, the thermal element being fixed in the intake pipe through which large volumes of water from several feet below the surface are continually pumped to the condensers.

An instrument of this sort installed in 1928 on the Peninsular & Occidental steamship *Henry M. Flagler*, one of the three Key West-to-Habana car ferries, provides the temperature record for one round trip daily while the ship is in operation. The south-

[1] Enlarged from paper presented at meetings of the American Meteorological Society, Des Moines, Iowa, Dec. 27, 1929, and the Association of American Geographers, Columbus, Ohio, Dec. 30, 1929. This is the first of a series of papers on The Gulf Stream and the Weather. (Cf. Gulf Stream Studies: General Meteorological Project, in the issue of the REVIEW of March, 1930.)